GHANA

GEOLOGICAL SURVEY

BULLETIN NO. 33

THE

GEOLOGY OF $\frac{1}{4}^{\circ}$ FIELD SHEET NO. 132—BOMPATA N.E.

Latitude 6° 45′ N.– 7° 00′ N. Longitude 1° 00′ W.–1° 15′ W.

(With geological map and sections to the scale 1:62,500 and other plates)

by

D. MASON, B.Sc.
Geologist

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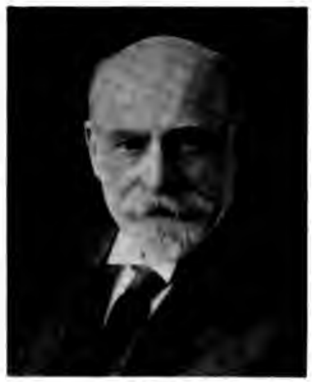

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FOREWORD

This description of the geology of Field Sheet 132 is mainly the result of the mapping of the area by Mason, who studied the rocks in the southern part of the Voltaian basin in 1957 and 1958. It includes, however, a few observations made in 1960 and 1961 by Krol and Moon, and the whole was compiled and edited by Murray, the Senior Geologist for the region, in 1962. Part of the chapter on the geological history of the Voltaian rocks was added by Bates, who has also considerably modified and revised the rest of that chapter.

This report adds considerably to understanding of the sedimentation which took place in the Voltaian basin, probably in Palaeozoic times. From the economic point of view the Voltaian rocks have little importance. Indeed their economic effect is negative, as they obscure a very large area of Precambrian rocks which might have been expected to extend economic prospects.

D. A. BATES
Director, Geological Survey.

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I. INTRODUCTION

The ¼° Sheet No. 132, covers an area lying to the north-east of Kumasi, in the Ashanti Akim district. The area is contained within the following lines of latitude, 6° 45′ and 7° north, and longitude, 1° 15′ and 1° west.

Agogo is the only town of any size. It is situated at a pass through the southern uplands, in the south-east corner of the field area, and can be reached by road from Kumasi via Konongo.

Other means of access to the area is provided by a laterite road from Kumawu which leads to Langs timber concession. This concession occupies the southern part of the Boumfum Forest Reserve. The only other roads are a laterite road from Agogo to Ananikrom in the north-east corner of the area and a laterite road leading to Wiawso in the south.

Mason mapped the geology of the area at intervals between December 1956 and June 1958 while the economic aspects of the area were investigated by Krol between January and April 1960. Moon, 1962, amended the granite-Birrimian contact in the south-west, and the succession in the Ongwam valley near Abodiem.

A large percentage of the area is underlain by gently dipping sandstones, shales, siltstones and grits belonging to the Voltaian System. These rest unconformably upon the Precambrian basement composed of Birrimian and Tarkwaian rocks. The Birrimian rocks are intruded by granites.

The main purpose of the field work was to study the succession at the southern edge of the Voltaian basin and to obtain information about the thicknesses and relationships of the various beds.

The survey was carried out by traversing on foot along roads, paths, rivers and forest boundaries as shown on the topographical maps. A traverse map is included with this report showing the traverses completed. (*see* Map 2).

The majority of the area is covered by thick forest, typical of Ashanti. These forests are preserved in four reserves which cover approximately 45 percent of the total area. Outside these reserves the land is utilized for cocoa and food farming except in the north where farming is restricted by poor soil and low rainfall. In this area the vegetation is limited to orchard scrub and grassland.

1. Previous Work

Previous work in the area by the Geological Survey include a traverse by N. R. Junner 1935 in the Wiawso-Kumawu area, and several traverses by T. Hirst (1942) who made an examination of the Voltaian rocks around Agogo while describing the Konongo Gold Belt.

2. Physical Features

The topography can be divided into six sub-divisions. The geology is closely related to the topography and so each sub-division is characterised by its particular type of rock.

The sub-divisions are as follows: (*see* Map 3).

(1) The area west of Amantana and south of the main escarpment.

(2) The area east of Amantana and south of the main escarpment.

(3) A triangular area, bounded on the south-west side by the edge of the main escarpment and on the north-east side by an impersistent, secondary escarpment, which follows a line through Timanti, Buhuri Hill, Manfrani Bepo and Taratara Hill to Adakem Hill.

(4) The region to the north-east of the impersistent secondary escarpment and bounded on the north-east side by the range of hills running south-east from Wabin through Pame, Bepotifi to Mpatampa.

(5) The division lying to the north-east of the fourth division and bounded on the north-east side by the Afram plain.

(6) The Afram plain.

The first area is underlain by Lower Birrimian rocks and intrusive granite, which give rise to low lying, undulating relief with open, flat bottomed valleys. The altitude ranges from 750 feet in the south to 1,000 feet at the foot of the escarpment which makes the northern boundary. This escarpment forms a fine feature, with vertical cliffs of sandstone, overlooking the ground to the south. The granite, which occupies the western part of the division, does not form a topographic feature.

East of the low lying ground, described above, is a region of diverse relief consisting of high rounded hills, such as Atem Hill, 1651 feet, and the Nyawa Range, 1850 feet, and deeply incised valleys. This, the second division, is underlain by Tarkwaian quartzites. The main escarpment forming the northern boundary is not so noticeable in this division, and is faced by hills of considerable height formed of quartzite.

At Nsuta, on the southern end of Adahem Hill, a partially uncovered " buried " hill of Tarkwaian quartzites can be seen where the overlying Voltaian rocks have been removed. It is therefore thought that the Tarkwaian hills were in existence in pre-Voltaian times and were buried by the Voltaian sediments. This is supported by the lack of Voltaian outliers on the crest of these hills.

The relief of the third region consists of high rounded hills and steep sided narrow valleys. These are bounded on the southern side by the main, south-facing escarpment, and on the north-east by the impersistent escarpment formed by the outcrop of the Dente massive sandstone. The two escarpments approach each other at Agogo and join on Adahem Hill. The diverse relief is due to the immature erosion of the clay gall sandstone series, which has given rise to high rounded hills such as Tebibepo, 1858 feet, Nsuta Bepo, 1820 feet, Munkumi, 1757 feet and Mosiaso, etc. These hills, which are the highest, occur along the south-west edge of the area and form part of the main escarpment. The average altitude of the hills decreases to the north-east and is about 1200–1250 feet above sea level on the north-east edge of the area.

The topography of the fourth division is controlled by the outcrop of the Dente sandstone. This sandstone dips gently to the north-east. The south-east edge of the outcrop thus forms an impersistent escarpment. In the north-west, the sandstone is not so eroded as elsewhere and so forms an example of scarp and dip slope topography. Farther south it is more dissected and around Agogo the topography consists of a series of irregularly shaped, flat topped mesas, capped by the sandstone.

The fifth division is under lain by almost horizontal stratawhich dips at low angles to the north-east. The topography is made up of a range of hills, formed by the Chirimfa arkosic sandstone, which is divided into three by the valleys of the Ongwam and Boumfum rivers. These hills have steep slopes on the south-west side where they overlook the dip slope of the Dente sandstone, while on the north-east side the hills slope gently down to the Afram plain.

The Afram plain occupies the north-east corner of the area and is essentially flat. The average altitude of the plain is 400 feet O.D.

3. Drainage

The main watershed closely follows the main escarpment and separates the south-flowing streams of the Pra and Anum basins from streams flowing north-east into the Afram.

The Ongwam river has broken through the main escarpment west of the area described and its head waters rise on the outside of the scarp. All the other streams, flowing to the north-east, rise inside the escarpment. In the south-east corner of the area, a case of river capture can be seen where a south-flowing stream, the Supuni, has captured its head waters from a stream flowing north-east.

The drainage pattern is of considerable value as an aid to mapping as it reflects the geology closely. For example, the tributaries on the east side of Ayifro river west of Taratara and Kumasi Hills all rise at the edge of the Dente sandstone outcrop and thus delineate it fairly accurately. The subsequent streams flowing across the Chirimfa shale and siltstone formation nearly always rise at the base of the Chirimfa arkosic sandstone and collect numerous obsequent tributaries from the underlying rocks. Streams flowing on the Dente sandstone are nearly always consequent streams and have fewer tributaries than those rising on the clay gall sandstone series or the Dente shale and siltstone series. The drainage pattern thus shows up the outcrops of the Dente and Chirimfa arkosic sandstones and indicates the type of rocks over which the stream or river is flowing.

The main drainage characteristics for each rock series is given below. The Afram river is considered to be the consequent river for the area.

(*a*) *The Agogo clay gall sandstone series and Dente shale and siltstone formation.*—Drainage pattern irregular, consequent and obsequent streams are common.

(*b*) *Dente sandstone formation.*—Drainage pattern parallel, river courses straight, consequent streams common, subsequent streams occur occasionally, obsequent streams rare.

(*c*) *Chirimfa shale and siltstone formation.*—Drainage pattern irregular and river courses characterised by curves. Streams mainly subsequent, obsequent rare.

(*d*) *Chirimfa arkosic sandstone.*—Drainage pattern parallel, river courses straight, mainly consequent; subsequent streams less common.

II. GENERAL GEOLOGY

1. GEOLOGICAL SUCCESSION

The consolidated rocks of the area range from pre-Cambrian Birrimian to post-Cambrian Voltaian, the latter covering more than three quarters of the area under consideration. The succession tabulated below is, with the exception of the intrusive rocks in descending order of age.

Upper Voltaian	Chirimfa arkosic sandstone formation. Chirimfa shale and siltstone formation.
	UNCONFORMITY
Lower Voltaian	Dente massive sandstone formation. Dente shale and siltstone formation. Agogo clay gall sandstone formation. Afram shale.
	UNCONFORMITY
Minor Instrusive	Amphibolite.
Tarkwaian	Banket quartzite.
Lower Birrimian	Phyllite, greywacke and schist.
Major Instrusive	Muscovite, muscovite-biotite and biotite adamellite and granodiorite of the Kumasi batholith.

III. THE BIRRIMIAN SYSTEM

The Lower Birrimian rocks are the oldest in the region and occupy the low ground to the west of Amantana. The rocks consist of phyllites and tuffaceous greywackes. The greywackes, when they are fresh, exhibit graded bedding and an excellent example of this can be seen in the road cutting just south-east of Wiawso.

In general the phyllites and greywackes are poorly exposed and pits were used to examine most of the area. Only in the area just south of the Voltaian escarpment could fresh exposures of these beds be examined, in stream sections such as can be found in the Nsuta and Suakwa valleys.

When unweathered, the phyllites are a light or dark grey in colour and the greywackes greenish or light grey, but when weathered both types become a deep red or orange colour unless leaching has taken place when they tend to become white or light grey.

These sediments were deposited in deep water into which fell periodic showers of ash. The latter increased in intensity in parts of the succession and gave rise to the beds of graded greywacke as seen near Wiawso.

The Lower Birrimian is intruded on the west side by the Kumasi batholith which has locally metamorphosed the country rocks into hornfels and schist.

There is no evidence to suggest the existence of Upper Birrimian rocks in the area and the Tarkwaian quartzites rest with unconformity upon the Lower Birrimian.

IV. THE TARKWAIAN SYSTEM

The quartzites of the Banket Series outcrop to the east of Amantona. They vary from an impure feldspathic variety to a pure white quartzite. In the thin section examined, sericite was developed between the elongated quartz crystals and small aggregates of tourmaline crystals, possibly of detrital origin, also occur.

The quartzites are intruded by two amphibolite sills.

V. MINOR INTRUSIVE ROCKS

AMPHIBOLITE SILLS

Two sills rich in hornblende intrude the Tarkwaian quartzites in the Nsuta and Afrabokrom area. Both sills strike north-south parallel to the strike of the quartzites and one is about 50 feet wide. To the north the sills disappear under the Voltaian basin. Southwards they can be traced down into the Bompata area.

Seen in thin section, the rock is composed almost entirely of the amphibole hornblende with subsidiary plagioclase feldspar. Small crystals of apatite are present and also ilmenite, mostly changed to leucoxene.

VI. THE GRANITIC ROCKS

The granite outcrops in the area west of Menam, between the Echuri valley and the western edge of the field area. The outcrop is bounded on the north by the Voltaian escarpment. The granites belong to the eastern part of the large Kumasi batholith which outcrops to the south-west and west of the field area and extends up to, and underneath, the Voltaian basin.

The contact of the granite is not well defined and does not form a topographic feature. The country rocks pass laterally into metamorphosed hornfels and biotite schists which in turn grade into the granite. This is comparable to the contacts of the batholith seen on the east side of Kumasi.

The granite contains numerous schistose roof pendants and xenoliths and the following granitic types can be recognised.

(1) Hornblende-biotite granite.
(2) Biotite granite.
(3) Muscovite-biotite granite.
(4) Muscovite granite.

The main accessory mineral is apatite.

The biotite-rich granites appear to form an outer zone around the muscovite-rich types, and are probably the results of assimilation of the country rocks by the granite.

VII. THE VOLTAIAN SYSTEM

Rocks of the Voltaian System have been subdivided into six lithological groups which may be recognised without difficulty in the field. The oldest, the Afram Shale Group, is not exposed at the edge of the Voltaian basin since it is overstepped by younger beds.

(a) LOWER VOLTAIAN

1. AFRAM SHALE GROUP

At several points along the Ongwam between the confluence of the Amobia and that of the Awurawso, stiff non-micaceous greyish white homogeneous clays were seen either in the stream bed or in a pit, overlain by micaceous river sand and it would appear that between Kajawarási and Enikwaso the river profile may cut through the lowest of the Agogo clay gall sandstone into the underlying Afram shales.

The only outcrop of Afram shale was seen in a pit excavated just north of Ongwama. In this pit was exposed a grey argillaceous shale which weathered to a grey-brown clay.

The thickness of the formation is not known.

2. THE AGOGO CLAY GALL SANDSTONE FORMATION

(*a*) **General.**—These sandstones, which are collectively the thickest members of the succession and attain a maximum thickness of 850 feet at Tebi Bepo hill, take their name from Agogo town where they were first mapped in detail. The sandstones form a marginal

belt 2 to 6 miles wide along the main escarpment of the southern edge of the Voltaian basin and have a regional dip of not more than 5° to the north or north-east. The south-western boundary of the outcrop coincides with the edge of the basin and the sandstones form the fine vertical cliffs which are characteristic of the escarpment between Abuhura hill and Amantana. The sandstones are also exposed in the sides and bottoms of all the rivers which have cut through the overlying beds. A completely enclosed inlier is exposed through the Dente lower shale and siltstone formation in the Fifiri valley.

The sandstones thin to the north-east. At the foot of the escarpment the series rests with flagrant unconformity upon the Precambrian. Over the Birrimian and associated granitic rocks the unconformity generally lies at 1,000 feet O.D., but varies between 900 feet and 1,600 feet over the Tarkwaian quartzites. The basal member is a coarse grit containing angular fragments of quartzites and phyllite derived from the underlying Precambrian rocks. Above this grit, two or more 5 to 8 feet thick bands of blue or green shale interbedded with siltstone occur. These bands are separated by beds of fine-grained greenish sandstone with clay galls.

The rest of the series is made up of a large thickness of clay gall sandstones. Included in this thickness are fine-grained orthoquartzites and arkosic sandstones, coarse rounded quartzo-felspathic grits, clay gall conglomerates and clay gall sandstones of a medium to fine-grained nature. Beds of sandstone rich in iron oxide also occur.

The clay galls are generally 0·5 inch in diameter, are green when fresh and it appears that most of the sandstones have a greenish tinge when fresh. The effect of weathering however generally oxidizes than to a purple colour. This is sometimes illustrated in the clay galls by a purple rim around a green clay gall. Dendritic markings of manganese are common on some of the clay galls.

In thin section the sandstones show a fair degree of sorting. Individual grains are mostly sub-rounded and many show distortion due to compaction. All the sections showed a high degree of compaction and cementation. The cement was mostly silica but feldspathic cement also occurred. One section of a coarse rounded sandstone showed the interestitial spaces to be filled by a quartzose matrix. This is probably typical of the coarser members of the succession.

Owing to the degree of compaction and cementation, the porosity of the sandstones is very low and in no section does the pore space exceed 20 percent.

(*b*) **The Agogo area.**—The sandstones are exposed in the edge of the escarpment south of Agogo and in the river valleys between the flat topped hills capped by the Dente sandstone. The main valleys in which the outcrops occur are the Pamfem, Owiri, Supuni, Abrodi, Kawire, Pampremsu, Kotobon and Fifiri. In the last-named the sandstones outcrop as an inlier through the Dente shale and siltstone formation.

Outcrops in the Agogo vicinity, apart from the escarpment and river sections, tend to be small and irregularly shaped rarely showing sections of more than 10 feet. Plate 1 shows typical examples of Agogo sandstone outcrops.

A comprehensive section of these sandstones can be studied on the north-east side of the Agogo-Konongo road between miles 14 and 16, just south of Fwidiem.

The base of the formation is not visible on the road but can be located in the Owiri valley east of mile 15. At this point a 10 feet section of grey-blue flat bedded shale overlain by 25 feet of fine-medium grained clay gall sandstones rests unconformably upon white, steeply dipping, Tarkwaian quartzite. The overlying sandstones can be traced up into the road where the following succession occurs.

Mile 14·7	Purple fine-grained sandstone with purple clay galls up to ½" in diameter	8'	
	Medium to fine-grained sandstone, dark red in colour	1'	
	Medium-grained white sandstone with large clay galls up to 1½" along long axis, grains sub-rounded.	1'	
	Thin bedded fine-grained brown clay gall sandstone	3'	
	Massive purple fine-grained sandstone	1'	
	Thin bedded clay gall sandstone	9'	
	Purply-white medium-grained sandstone	1'	
	Thin bedded medium-grained clay gall sandstone	1'	
14·8	No outcrops		
14·9	Fine-medium grained purple and white clay gall sandstone. Maximum thickness of any one bed not more than 9" Ripple marked.	2'	6"
15·0	No outcrops		
15·6	Thin bedded medium-grained clay gall sandstone with white spots of kaolin	3'	
	Ripple marked hard fine-grained white sandstone		9"
	Thin bedded medium-grained clay gall sandstone, reddish-brown in colour	23'	
	Thin bedded fine-grained clay gall sandstone. Clay galls green in colour	6'	
	Similar to above. Individual beds lenticular and not more than 9" thick. Some sandstones rich in feldspars others with abundant clay galls. Sandstones occasionally ripple marked.	113'	
15·8			

(*See* Plate 1)

The thickness of the above section is 300 feet from the shale to the highest sandstone seen but much of the lowest 50 feet is not exposed.

Joints in the sandstones follow two main directions, 080° and 150°.

The ripple marks are not easy to classify accurately but both symmetrical (worn type) and asymmetrical (current type) ripple marks appear to be present.

At Agogo town the sandstones have a proven thickness of between 595 feet, 660 feet and 790 feet in boreholes A8, A6, and A5*a* respectively, and overlie Tarkwaian quartzites. The strata in these boreholes are mainly clay gall sandstones except for a few subordinate shale bands.

Most of the other sandstone outcrops in the Agogo area are similar to the outcrops already described with the exception of occasional exposures which contain beds of coarse sandstone rich in feldspar (*see* Plate 3). One of these bands can be seen in the Kawire valley just north-east of BHA6 where a thin band of coarse sandstone with rounded grains of quartz and feldspar in a fine-grained sandstone matrix with small fragments of clay outcrops, together with some medium-grained clay gall sandstones. These coarse bands are rare, however, and are not characteristic.

(*c*) **The Pentempa-Abasi area.**—The outcrop in this area is very large and continuous, the overlying beds having been completely removed by erosion. As in the Agogo area, the best outcrops occur along the edge of the escarpment and in the river valleys. The formation is also exposed in a thin outcrop down the Boumfoum river from Oboachudie to the Kotobon confluence where the outcrop connects up with the Kotobon and Pampremsu outcrops.

North-east and east of Amantana, outcrops of a basal quartz conglomerate can be found on the path to Pentempa, and also east of Befwe village. The conglomerate is rich in quartz and quartzite fragments together with fragments of phyllite. This type of basal facies is unusual and has been observed only in the Amantana area.

In the escarpment north of Wiawso the sandstones form cliffs 600 feet high made up entirely of thin-bedded clay gall sandstones. On the west flank of Tebibepo at the western

end of these cliffs the base of the sandstones can be seen in the small stream which flows south-west down the escarpment. The stream bed is made up of a series of small waterfalls formed by thin micaceous shale beds interbedded with beds of clay gall sandstone. These beds have a slight dip to the north-east and overlie unconformably. steeply dipping Lower Birrimian phyllites and greywackes which are exposed immediately below the lowest shale band.

A similar type of outcrop can be seen in the Nsuta valley where, at a point just over one mile upstream from the forest boundary line, an outcrop of 10 feet of grey-blue shale interbedded with sandstone lies unconformably on a reddish coloured biotite granite. These shales pass upwards into more than 200 feet of thin-bedded clay gall sandstones which are exposed upstream and dip 5–8° to the north-east. Major joints in these sandstones strike at 90°.

Away from the escarpment the formation can be observed in smaller outcrops in the Ninai river and Boumfum. West of Obuachudie the latter river flows through a 700 feet gorge of clay gall sandstones similar to those described above which dip at 7° to the north-west.

At Nankruma, underlying the Dente sandstone and dipping at 8° eastward, a hard pinkish orthoquartzite outcrops, under which clay gall sandstones occur. The quartzite apparently is the top of the Agogo sandstone in this area.

Agogo sandstone outcrops in the Ninai valley form a series of rapids just south-south-west of Eduamuyao. The sandstone in this area is a pinkish clay gall type and dips 5° north-eastwards. Many other outcrops also exist in this area but do not warrant detailed description since they are similar to those already described.

(*d*) **The Ongwam Valley.**—The Agogo clay gall sandstone outcrop makes a deep embayment into the Dente sandstone down the Ongwam Valley and is also exposed in an inlier east of the Bomfobiri waterfall. Exposures occur in the Ongwam below forest boundary pillar No. 71 of the Bomfa Reserve where the sandstone dips at 5° to the north-east. Half a mile east of this outcrop, the Dente massive sandstone outcrop crosses the river and forms a series of rapids and Bomfobiri waterfall.

East of Bomfobiri falls a further 150 feet of Agogo clay gall sandstone is exposed before the base of the sandstone is reached near the Ninai-Ongwam confluence. Below this point the sandstone outcrops run down each side of the Ongwam below the Dente massive sandstone, and the outcrops disappear under the Lower/Upper Voltaian unconformity at Abodiem.

The presence of clay galls throughout these rocks indicates that contemporaneous erosion was taking place in some area near the zone of deposition. The occurrence of thin bedding, ripple marks and suncracks all point to deposition in a shallow water environment. The constituents of the sandstones and shales, viz., quartz, feldspar and detrital muscovite indicate that the materials were derived from granitic rocks and greywackes.

The evidence undoubtedly shows that those sediments were deposited on the shallow shore of a large sea or brackish lake and were derived by erosion of the Precambrian which lies to the south of the Voltaian basin.

3. THE DENTE SHALE AND SILTSTONE FORMATION

The name of this formation is taken from the Dente range which lies about 2 miles south-west of Agogo.

The type section occurs on the north side of the Dente range at the bottom of Dentebuom cliff, where a sixty feet section of interbedded shale and siltstone with lenticular beds of fine-grained sandstone can be studied in detail. The cliff forms an excellent feature and the section is readily accessible (*see* Plate 5).

The formation lies conformably on top of the Agogo clay gall sandstones and is followed without a break in deposition by the Dente sandstone. The beds reach their greatest thickness in the vicinity of Agogo where they are 240 feet thick. Away from Agogo the formation thins rapidly and it is doubtful whether it is continuous throughout the area. Small exposures of shales belonging to this formation have been observed at the following points; 0·25 mile west of Obuachudie, 1 mile south-west of Tinanti and in the cliff north of Adenyensu. The facies does not occur between the Dente sandstone and Agogo sandstones at Bomfobiri waterfall nor at the Nankruma exposure.

The shale beds in the formation are thin being generally less than 1 foot in thickness and closely inter-bedded with the siltstones (*see* Plate 6). In thin section the siltstone is well sorted, compacted, and cemented by quartz. The grains are extremely angular (*see* Plate 11). Both the shales and the siltstones are very micaceous and when fresh are a light greeny-grey colour.

The lenticular beds of fine-grained sandstone which are interbedded with the shales and siltstones also tend to be greenish grey in colour and carry small amounts of clastic mica. Washouts representing contemporaneous erosion can often be seen in the Dentebuom section (Plate 7). The irregularities in the bedding planes has resulted in uneven compaction which can be seen in most parts of Dentebuom cliff (Plate 7). Ripple marks (Plate 8) and suncracks (Plates 15 and 16) together with occasional bands showing rain spots are common in the formation.

The rapid lithologic alternation of the shales, siltstones and sandstones in this formation together with the presence of washouts, suncracks and rain prints all point to extremely shallow water conditions similar to the Agogo sandstone formation period, and there appears to be no change in conditions between the two formations.

The Dente shale and siltstone formation also contains occasional beds of coarse sandstone and a minor section of one of these revealed the presence of quartzite grains obviously derived directly or indirectly from the Tarkwaian System. The clastic mica and other constituents were probably derived from granite sources to the south, as were the Agogo sandstones.

4. THE DENTE MASSIVE SANDSTONE FORMATION

This formation also takes its name from the Dente range where it was first studied in detail.

The type exposure is at Dentebuom cliff where the sandstone forms a 150 feet cliff on top of the Dente shale and siltstones (*see* Plate 11).

In the Agogo area the sandstone outcrops as several outliers capping all the higher hills such as Adahem, Dente, Abruwanfu, Kotobon and Hamahama. To the north-west of Agogo, from Taratara Hill onwards, the outcrop becomes more continuous and large areas between Nankruma, Kajawarasi and Buhuru are underlain by the sandstone. The Pame basin is also floored by the Dente sandstone.

Lithologically the sandstone is an orthoquarttzie and is made up of medium to coarse rounded grains of quartz held in a quartz cement in a fine-grained quartz matrix (*See* Plates 18, 19, 20). False bedding is extremely common and can be seen in the cliff south of Brengo and in the numerous outcrops on the dip slope of the sandstone (*See* Plate 22.) Lenticular conglomeratic bands of quartz pebbles, up to 2 inches across, are interbedded with the sandstones.

The thickness of the sandstone varies up to a maximum of 350 feet, the latter thickness being attained at Kumasi Hill, north-west of Agogo.

In colour, the formation varies from white to a pinkish brown and weathers to a semi-honey-combed appearance on exposed surfaces.

The rock is extremely resistant to weathering and the edges of the outcrop are well marked by cliffs, waterfalls (Plate 21), and steep slopes covered with sandstone boulders. The dip slope of the sandstone is generally characterised by rock pavements as shown in Plates 22 and 23.

The sandstone rests conformably upon the Dente shale and siltstones but deposition ceased after the sandstone had been deposited and an unconformity occurs between the Dente sandstone and the overlying Chirimfa formations.

(b) THE UPPER VOLTAIAN

1. Chirimfa Shale and Siltstone Formation

The Chirimfa shale and siltsones rest unconformably upon the underlying Dente sandstone and older formations in the Ongwam and Boumfoum valleys but elsewhere the unconformity is between the Chirimfa shale and siltstones and the Dente sandstones only.

In the Pame area, the formation is exposed in the steep slope below Pame Hill. The rocks in this area consist of fine-grained, micaceous siltstones which vary in colour from very dark grey to a deep reddish-purple and subordinate beds of green, purple or red, micaceous shale. The siltstone also contains feldspar which in most specimens is now kaolinised. The formation can be easily recognised in the field by the presence of a high percentage of clastic mica, often distributed along the bedding planes, but also scattered haphazardly through the rare massive siltstones, and by the colour of the sediments which are always extremely dark red or grey and rich in iron or ferromagnesian minerals. Clastic biotite is very common and is a useful identification mineral. Plate 18, shows a specimen of siltstone, from Pame cliff, rich in mica which is distributed along the bedding plance. Other outcrops of shale and siltstone belonging to this formation can be seen in the Amoakofu area, in the tributary stream beds of the Fifiri, on the north-east bank of the Kotobonsu, in the tributaries flowing into the Bomfam, east-north-east of Nankruma, in the Sutri stream, and in the Ongwam valley near Abodiem. In all these exposures the specimens are similar to the Pame types.

The main rock type of the group is a dark red, fawn or grey micaceous arkosic siltstone. Shales are subordinate, but where exposed are usually red in colour and micaceous.

The thickness of the formation is approximately 200 feet but it has a tendency to thicken to the north-east and to thin towards the south and south-west.

These sediments are waterlain and the presence of biotite and feldspar suggests that the transportation and deposition of the sediments was rapid and Prevented the complete disintegration of the parent material, which was probably an area of Precambrian granite and metamorphic rocks. The sea or large lake in which they were deposited was smaller in extent than the Lower Voltaian sea. The coast line against which the sediments thin out west of Atonsu was probably lined with sand dunes and subject to desert conditions. Some of the material including the various beds of the formation may therefore have been carried by the wind before being deposited under shallow water.

2. The Chirimfa Arkosic Sandstone Formation

This formation outcrops in three oval shaped areas separated by the valleys of the Ongwam and Boumfuom rivers.

The sandstone which follows conformably on the underlying series, is predominantly deep red or purple in colour, medium to fine-grained and is always characterised by white spots of kaolin, after feldspar. Less commonly the sandstone may be white. False bedding is not common in the area under consideration but to the north-west on the road between Kwamang and Jadiako " dune " bedding on a large scale may be observed in the sandstone.

The maximum thickness of the sandstone is 450 feet. The Chirimfa sandstone in the Ongwam area was deposited in a shallow lake, which was bordered by a desert shore to the north-west of this area.

(c) CORRELATION OF THE VOLTAIAN SEDIMENTS

Previous work on the Voltaian System has divided the sediments up into the following succession—

V3*b* Upper quartz sandstones.
V3*a* Clay gall sandstones.
V2*b* Red, green and purple arkosic sandstones and shales (Obosum).
V2*a* Akroso conglomerate, grits, arkosic sandstones and mudstones (Oti).
V1 Quartz sandstones with pebbly grits and clay galls (Basal sandstones).

Junner, 1946, describes the strata outcropping at Drobonso as part of the Obosum beds. These beds can be traced across the Afram plain and are equivalent to the Chirimfa arkosic sandstone and Chirimfa shales and siltstone formations described in this report.

Accordingly if these beds are Obosum in age, the Dente sandstone—Agogo clay gall sandstones formations are, in age, probably equivalent to the Oti Series since they underlie the Obosum beds.

In opposition to this correlation, Mitchell 1953 has described the sediments in the Kom-Mankrong area and separated them into Oti and Obosum series overlain unconformably by the Upper Sandstones. The latter are composed of "well jointed, white, medium to coarse grained, quartz sandstones and quartzites resting unconformably on the V2*a* and V2*b* groups, these are directly overlain by red and purple kaolin speckled sandstones." If these Upper Sandstones are taken to be equivalent to the Dente Sandstone and Chirimfa arkosic sandstone formations, respectively, then all the sediments from the basal shales of the Agogo clay gall sandstone formation upwards belong to the V3 group, the Upper Sandstones.

The succession put forward in this report divides the Voltaian strata on the southern edge of the Voltaian basin into the Upper and Lower Voltaian.

The Lower Voltaian includes everything up to the Dente Sandstone and is equivalent in part to Mitchell's Oti and Obosum series and the white orthoquartzite of his Upper Sandstones.

The Upper Voltaian is made up of all the sediments above the Dente sandstone and is equivalent to Junner's Drobonso, Obosum beds and Mitchell's red and purple arkosic sandstones from the Upper Sandstones.

VIII. GEOLOGICAL STRUCTURE

The field area covers the southern edge of the geological and topographical Voltaian basin and a small area of highly folded Precambrian basement to the south of the basin. The structure of the region can therefore be considered under two headings.

(*a*) The highly folded Precambrian basement.

(*b*) The Voltaian basin.

1. THE PRECAMBRIAN BASEMENT

The structure of the basement is characterised by isoclinal folding. The regional strike of the rocks is to the north-east. Within the Lower Birrimian outcrop local strikes may vary between 10° and 55° and the rocks dip steeply to the north-west or south-east. Vertical dips are common. Inverted graded bedding in the Wiawso area indicates that the main thrust during the folds have been overturned and that the main thrust during the folding was from the north-west.

The Tarkwaian quartzites rest unconformably on the Birrimian System. They are also folded isoclinally. The folds cannot be detected in the field area owing to lack of outcrops and suitable marker beds but are described by Hirst, 1942, in the Konongo area to the south, as being a series of vertical isoclinal folds.

Two amphibolite sills intrude the quartzites and have been folded with them, so that they now have a vertical attitude. The sills strike north-south and disappear northwards under the Voltaian basin.

2. The Voltaian Basin

The structure of the Voltaian basin is very simple and apart from some slight deformation and faulting, the strata are still in the attitudes in which they were deposited.

The rocks were deposited in a topographically wide, shallow, pre-Voltaian basin and represent the shore line and deeper water deposits of the Voltaian sea which occupied it. The deposits fall into two groups, the Upper and Lower Voltaian, which are separated by a marginal unconformity at the edge of the basin but are probably conformable away from the shore line.

The Upper Voltaian sediments outcrop within the Lower Voltaian and indicate that the area of deposition was reduced between the two periods.

Evidence of slight deformation is given by the base of the Dente sandstone formation which has been cleared in the Buhuri Hill area. Between Timanti, Buhuri Hill and Mantrani Bepo the base of the sandstone rises from 1,050 feet to 1,250 feet, and then descends again to 1,050 feet respectively, indicating a gentle doming of the strata. Farther to the south-east in the Agogo area the base of the sandstone rises to 1,600 and 1,750 feet.

Near Agogo, two of the Dente sandstone outliers are slightly synclinal. These are Dente Hill and the hill just north-west of Agogo.

Faulting in the Voltaian is confined to the south-east corner of the area. Four normal faults, belonging to a system of block faulting which follows east-north-east and north-west directions, have been detected and affect all the Voltaian strata.

The faults are as follows:—

(*a*) *The North Agogo fault.*—This fault passes north of Agogo from the Panfem valley down the lower Kruwire valley. It has a downthrow of 250 feet to the north-west and throws the Dente shale and siltstones against the Agogo sandstones.

(*b*) *The South Agogo Fault.*—The downthrow of this fault is 50 feet to the north-west. The line of the fracture passes south of Agogo down the Upper Kruwire valley and terminates at its north-east end against the North Agogo fault.

(*c*) *The Ayongkura Fault.*—This fault runs south-east from Ayongkura towards Onyimso off the south-east side of the field area. The fracture terminates against the North Agogo fault near Ayongkura and has a downthrow of 200 feet to the north-east. The fault downthrows the Dente sandstone and causes an increase in the width of the sandstone outcrop north-east of Mayera.

(*d*) A small connecting fault running northwest-southeast between the North and South Agogo faults, just north-east of Fwidiem. The amount of downthrow is not known.

The evidence for these faults is based on the following observations:—

(*a*) The Water Supplies Division borehole No. A4 in the valley between Agogo rest-house and Agogo town proved 94 feet of grey shales, etc. overlying clay gall sandstones. To the south of this borehole, on the surface and in the roads and ditches of Agogo town, clay gall sandstone outcrop at the same level.

There must therefore be a major dislocation between the borehole and the town, which downthrows the Dente shale and siltstone against the Agogo sandstones. This is the North Agogo fault.

(*b*) and (*d*) These two faults are postulated to explain the small outlier of Dente shale and siltstone near Fwidiem which although dipping to the south is not exposed in the Agogo-Konongo road section south of Fwidiem.

(*c*) The Ayongkura fault is based on the displacement of the Dente sandstone outcrop at the end of Mayera Hill, and the downthrow is calculated on that displacement.

All the formations of the Voltaian System are well jointed and the joints tend to follow two major trends nearly at right angles to each other. These trends lie roughly between 0°–30° and 270°–300°. The latter set appear to be the more important.

The unconformity below the Upper shale and siltstone series indicate intraformational movement. The upturning and slight folding at the south-east edge of these series further ndicates post-Voltaian movement probably associated with the faulting.

IX. GEOLOGICAL HISTORY

1. Precambrian Period

The sequence of events during this period commenced with the deposition of phyllites and greywackes in a deep-water geosynclinal environment during the Lower Birrimian.

At the end of the Birrimian System, tectonic movements took place and the strata were folded, intruded, uplifted and subjected to erosion. The axes of the folds trend north-east to south-west, the main compression coming from the north-west.

The granite intrusion is also elongated in a north-easterly direction and most of the xenoliths and roof pendants follow this trend. As already stated the granite was intruded by the processes of granitization and assimilation of the country rocks and was probably emplaced at depth.

The uplift of the folded Birrimian rocks resulted in a long period of erosion, which in the area under discussion, may have completely removed the Upper Birrimian strata.

This erosional period was followed by the deposition of the Tarkwaian quartzites. These were deposited in a relatively narrow, north-east-south-west elongated geosyncline.

After the deposition of the quartzites had taken place they were intruded by several basic sills which are most concordant. These sills were later folded with the quartzites during the post-Tarkwaian diastrophism.

During this post-Tarkwaian period the Birrimian and Tarkwaian strata were subjected to strong compression from the north-west and were folded into a series of isoclinal folds, the Birrimian rocks being overfolded slightly in some areas.

No further deposition then occurred in the area until the appearance of the Voltaian sediments. The area was subjected to a long period of erosion however prior to the Voltaian period.

2. The Pre-Voltaian Land Surface

Before the Voltaian deposition commenced it is apparent that the pre-Voltaian rocks had been subjected to a long period of erosion. Careful study of the unconformity between the Voltaian and the underlying Birrimian and granitic rocks has revealed that the Voltaian sediments were deposited on a surface which had a gentle slope of 3–5° to the north-east in this area.

The level of this surface over the Birrimian outcrop, at the edge of the escarpment, is now at approximately 900 feet above sea level. Over the granite areas it is higher and averages about 1,250 feet along the extreme edge of the escarpment.

Over the Tarkwaian outcrop the pre-Voltaian surface is characterised by high isolated inselbergs and small ranges formed by Tarkwaian quartzites. The relief of these quartzites results in the base of Voltaian varying in height from 1,000 feet to 1,500 feet in this area. Some of these hills rose to nearly 1,000 feet above the general level of the pre-Voltaian surface and were probably only buried in late Lower Voltaian times. An example of a partially buried hill which is overstepped by Voltaian sediments, can be observed at the present time in the escarpment near Insuta, where quartzite outcrops up to 1,500 feet at the south end of Adhem Hill.

3. THE VOLTAIAN PERIOD

Study of the Voltaian basin as a whole shows that before the formation of the basin the River Volta, and its main tributaries, the White, Red and Black Volta rivers, were flowing in valleys in approximately the same positions as those of the present day. These valleys may be seen in the Precambrian surface, now infilled with Voltaian sediments, where they enter the Voltaian rocks from the Precambrian.

The Voltaian basin is bounded on the east by the prominent hill range of rocks of the Togo and Buem formation. It has been stated elsewhere (Bates, 1957) that the line of the Togo range has been a focus of movement from middle Precambrian times to the present. The north-western edge of the Dahomeyan has repeatedly been the shoreline of successive geosynclines, ranging in age from the Birrimian to the Buem, while recent movements on the same line are shown by down-faulted blocks of unconsolidated recent sediments along the Togo-Dahomeyan boundary, and by actual changes of level which were measured after the earthquake of 1939. Conglomerates in the Voltaian sediments, in both the eastern and western parts of the basin, contain large pebbles including lavas of unmistakeable Buem age, suggesting that the Buem rocks formed a prominent hill feature at that time from which these pebbles could be distributed over a wide area.

Bearing these facts in mind, it seems that the Voltaian basin was formed by subsidence due to down-warping of the basin of the Volta river and its tributaries, accompanied by movements on the line of the Togo hill range which dammed the river where it crosses the range, near the present Volta gorge at Ajena. For an account of the curious nature of the river bed at the gorge, which must be due to successive faultings of the Togo rocks across the river bed, the reader is referred to Tevendale, 1957.

The Voltaian sediments in the basin as a whole consist mainly of shales, arkoses, and sandstones. Ripple marks and clay galls are all common, and reflect deposition in shallow water. Some of the sandstones were deposited under certain conditions. The sediments appear to represent deposition over a long period of time, under changing climatic conditions. Thus great thicknesses of purple shale and arkose suggest deposition in a Voltaian lake surrounded by a desert landscape, upon which sand dunes were deposited; but in another part of the sequence the presence of green shale with tillite reflects a cold period. The extent of the lake waxed and waned; at one horizon the tendency for the formation of magnesian limestones, amounting in some localities to thick and extensive beds, suggests evaporation over a considerable period of sediment-free waters. In spite of these variations of climate and the lapse of time represented by them, all the sediments are remarkable for a complete absence, with the possible exception of Collenia, of any traces of organic material, either plant or animal. Perhaps the absence of traces of carbonaceous matter is the most remarkable feature. It is concluded that the Voltaian sediments were deposited in a lake, in the later stages a dry basin, surrounded by a barren and inhospitable countryside.

(a) The Lower Voltaian.—The drowning of the basin in this area must have been rapid and yet relatively tranquil as the first deposits to be laid down were fine thinly interbedded shales and siltstones, with occasional beds of fine-grained clay gall sandstones.

The varved appearance of the shales and siltstones indicates that deposition was rhythmic The infilled suncracks which the shales exhibit in the Buoansa area suggests that the water was extremely shallow and often evaporated exposing the newly deposited clay to rapid dessication and subsequent cracking.

Conditions at the beginning of the Voltaian therefore appear to have been quiet with periodic floods of water across a low lying plain. These floods carried silt across areas of dessicated mud, infilling the suncracks and preserving them. The siltstones grade upward into the shale indicating periods of stagnation which allowed the extremely fine clay and colloidal material to settle.

The sheet of water eventually evaporated exposing the recently deposited mud surface to dessication. The beds of fine-grained sandstone are forerunners of the next period and indicate an increase in the carrying ability of the agents of erosion and probably an increase in the rainfall of the area.

Around the Tarkwaian hills a change in texture occurs in the basal facies with the presence of coarse conglomerates. These were derived from the steep sides of the hills and are made up of quartz and quartzite fragments with some smaller pieces of phyllite.

After the basal facies, deposition of coarser sediments commenced. There is no sudden change between the two but higher in the succession the clay gall sandstone beds become more dominant until they form the whole section.

The Agogo clay gall sandstones, which reach a maximum thickness of 850 feet represent a long period of deposition under stable conditions.

Deposition of these sandstones probably took place in deeper water than the basal shale facies but, not far away, active erosion of mud banks, or exposed areas of clay, was taking place. The clay galls which abound in the sandstones were derived from the mud banks. The sandstones are poorly sorted. It therefore seems unlikely that they have been transported far. Grains of quartzite, quartz and feldspar together with clastic white mica indicate that the material has been derived from an acid granitic area. This granitic source must have lain to the south, south-east or south-west as the deeper parts of the Voltaian basin lay to the north and north-east.

A quieter period followed the deposition of the Agogo sandstones and is represented by the Dente shale and siltstones. These are very shallow water deposits and were probably large mud banks which were often above water level. Suncracks, rain prints and washouts in this formation all indicate that the deposits were subject to subaerial erosion on occasions.

The Dente shales and siltstones are followed by a period of coarser sedimentation which resulted in the deposition of the Dente sandstone. The sandstone is fairly well sorted and is an orthoquartzite. Bands and lenticular beds of micro-conglomerate are interbedded with the medium-grained sandstone. The sandstones often exhibit current false bedding and appear to have been deposited in an offshore, coastal environment and may represent the near-peneplanation of the area to the south of the basin (Krynine 1948).

The Lower Voltaian was brought to a close by a withdrawal of the sea and the subsequent su baerial erosion of the exposed Dente sandstone, etc.

The areanaceous coastal deposits all thin towards the north-east and may pass into the Afram shales which are possibly the deeper water equivalent of the shore line facies. These shales are grey in colour and the occurrence of limestone has been recorded in similar beds to the south-east (Mitchell, 1953).

(b) The Upper Voltaian.—Sedimentation in this period commenced with the Chirimfa shale and siltstone formation. The area of deposition at this time was considerably reduced in relation to the Lower Voltaian. The coast line during the deposition of these shales appears to have been just south-west of a line down through Atonsu and Kwamang.

Although the retreat of the water caused a marginal unconformity along the shore of the basin it is probable that north of the Afram valley sedimentation was continuous and therefore the Chirimfa shale and siltstones formation is continuous with the Afram shales. In the area between Bepotifi, Pame and Kwamang however the Chirimfa shale and siltstone rest unconformably on the Lower Voltaian.

The source of the Chirimfa shale and siltstone must have been different to the Lower Voltaian as they are extremely rich in biotite and muscovite in many places. The presence of these micas indicates that the deposits have not been transported far and were protected against mechanical and chemical disintegration. Although there is no evidence available the writer would suggest a westerly source for these sediments which were carried by rivers draining into the basin from that quarter.

With the advent of the Chirimfa arkosic sandstone, climatic conditions changed and a period of aeolian deposition in a desert facies commenced.

At this time the shore of the lake had retreated and the Chirimfa sandstone passes from a massive water-lain sandstone to a dune bedded type.

The dunes were controlled mainly by an on-shore northerly wind, the influence of which caused the dunes to advance southwards overlapping the Chirimfa shale and siltsone and encoaching on the partly eroded Dente sandstone.

At the same time as the dunes were being deposited, a similar arkosic sandstone but devoid of bedding was being deposited in the Voltaian lake. The massive nature of this facies suggests that the sandstone was not subjected to currents or any other disturbing factors during deposition. This may be due to protection given by the Ejura sand bar to the north.

To the north and north-east the arkosic sandstone thins and passes into shales and thin-bedded limestones which represent the deeper water facies of the Upper Voltaian.

In the Ejura area the conditions, at the time of deposition of the Chirimfa sandstone, appear to have been shallow and suitable for the production of a sand bar which was thrown up by waves caused by the north wind. The sand bar occurs parallel to the coast and about nine miles from it and probably acted as a shield to the deposition of the massive, water-lain, Chirimfa sandstone. The Ejura sandstone sand bar now forms the feature known as the Ejura escarpment.

At the end of the Upper Voltaian, the Voltaian lake became silted up and sediments in the middle of the basin became coarser passing upwards from shales into medium-grained arkosic sandstones. Deposition finally ceased at the end of the Voltaian with the deposition of the arkosic sandstones of the Sene Formation.

(c) Deformation and Faulting.—After deposition had ceased the Voltaian rocks were at some time subjected to gentle deformation from the south-east which resulted in the damming of the strata in the Buhuri Hill area. At the same time probably the strata in the Agogo area and to the south-east of Agogo were faulted by a series of block faults along east-north-east and north-west directions. These faults appear to be the reflection of fractures and movements along the line of the Tarkwaian geosyncline. It is not possible to date the age of these movements more accurately than post-Voltaian.

4. THE TERTIARY PENEPLAINS AND SCARP DEVELOPMENT

Within Ghana, two major erosional surfaces are recognised. The older occurs between 1,700 feet and 1,250 feet and the younger rises from 180 feet on the coast to 1,000 feet at the foot of the Voltaian escarpment.

The ages of these two peneplains is not known for certain but a Jurassic age is suggested for the older and a late Tertiary age for the newer surface.

Both of the surfaces are represented in the area under discussion.

The older surface controls the height of the main Voltaian escarpment and is between 1,900 feet and 2,000 feet along the edge of the Voltaian basin.

This surface appears to slope to the north-east and is believed to be represented on the flat tops of Hamahama Hill, Kumasi Hill and the levelled top of Pame Hill at 1,100 feet inside the Voltaian basin. Manfroni Bepo 1,392 feet is also believed to be a remnant of this early surface. The younger surface is only represented in the south of the area where it abuts against the Voltaian escarpment, at about the 1,000–1,100 feet level.

The slope of this peneplain has considerable effect on the outcrop of the Voltaian sediments and is responsible for the lack of Voltaian outlier south of the escarpment and the relatively straight northwest-southeast trend of the cliffs.

Since the slope of the peneplain is to the south-west and the base of the Voltaian slopes to the north-east, the divergence of the two planes automatically precludes the possibility of Voltaian outliers occurring at any distance from the escarpment.

The main Voltaian escarpment is, in the writer's opinion, the direct result of this younger erosion surface which, during its formation, attacked the edge of the Voltaian outcrop and by rapid undercutting of the sandstone formed the forerunners of the high cliffs seen at the present time.

The drainage within the Voltaian basin appears to have been inaugurated on the older peneplain which sloped to the north-east. As the slope of the peneplain coincides with the regional dip of the Voltaian sediments, the drainage pattern thus developed was of a consequent type.

Originally it seems probable that all the drainage flowed into the Volta in the centre of the basin but after a time inequalities in the hardness of the rocks and the rapid retreat of the headwaters of certain streams has led to a modification of this earlier pattern.

The most important river in this respect is the Afram, which developed, as a subsequent tributary to the Volta, on the Afram shales and has rapidly cut back and captured most of the drainage from the southern uplands.

In the area under discussion the upper parts of the captured consequents streams within the southern uplands have themselves developed subsequent and obsequent tributaries, on the softer strata. This has led to the formation of a well developed scarp and dip slope topography in the area between Agogo and Kwamang.

The geological factors which have enabled these scarps to develop are the relative softness of the Chirimfa and Dente shale and siltstones formations and where the Chirimfa shale and siltstone thins out, the feature formed by the Chirimfa sandstone merges into the Dente sandstone scarp.

The final deposits in the area consist of recent alluvial sands, gravels and clays in the rivers, detrital sandy soils over the Voltaian sandstone, Tarkwaian and granite outcrops and clayey soils over the Voltaian shales and Birrimian outcrops.

X. ECONOMIC GEOLOGY

1. MINERAL DEPOSITS

(a) Gold.—Although the area lies across the north-eastern extension of the Konongo gold belt, no auriferous quartz reefs or placer deposits of gold have been found. The streams draining the Lower Birrimian outcrop between the Tarkwaian quartzites and the granites were panned but only the gravels of the Menom stream and the Worapon were found to contain a few colours of gold.

For the following reasons it is unlikely that there are any gold reefs in the area under discussion. In the Konongo gold belt, the Upper Birrimian forms the country rocks for the gold-bearing quartz reefs, and the age of these reefs is pre-Tarkwaian (Hirst 1942). No Upper Birrimian rocks outcrop in the field area as they were removed by erosion, prior to the deposition of the Tarkwaian which rests unconformably on the Lower Birrimian. It is therefore probable that any gold-bearing reefs were removed, with the Upper Birrimian, by erosion during the pre-Tarkwaian period.

It is possible that auriferous reefs do continue under the Voltaian basin but it would be almost impossible and uneconomical to attempt to locate them.

(b) Other Mineral Deposits.—The concentrates taken from streams draining the Lower Birrimian outcrop were very poor in minerals other than quartz, staurolite, garnet and magnetite. The staurolite and garnet were common in concentrates from the Menom river which drains the edge of the granite outcrop. No diamonds or minerals of economic importance were found.

2. DIMENSION STONE

(a) Precambrian Area.—There are no possible quarry sites in areas underlain by Lower Birrimian and granite.

The Tarkwaian area, by virtue of its marked topography may be quarried at several localities the most favourable, by virtue of access, being Atem Hill. Banket quartzite is well exposed, on the northern slopes of this 1651 feet high hill and a quarry face more than 100 feet high and 60 feet wide could be established. The quartzite is fine-grained and light grey in colour: sericite is developed and the rock is variably feldspathic. Concentration of magnetite and haematite emphasises current bedding.

(b) Voltaian Area.—Quarry sites suitable for producing stone are located as follows:—

(1) *In the cliffs north of Wiawso.*—The rock, Agogo clay gall sandstone, could easily be quarried in the main escarpment and can be used for flagstones and walls.

(2) Many other small cliffs along the edge of the escarpment could be quarried and the localities are obvious from an inspection of the topographical map.

(3) To the west of the Agogo-Onyimso road where the road climbs over the edge of Dente hill.

The rock is Dente massive sandstone and a quarry face could be established in the cliff formed by the sandstone just to the west of the road. The stone would be suitable for building and for concrete aggregate.

(4) Any of the Dente massive sandstone formation cliffs which are accessible will provide reasonable quarry sites.—*See* geological map for distribution.

3. SAND DEPOSITS

(a) Precambrian Area.—Most of the rivers draining the Precambrian can provide small amounts of sand for local usage but large deposits are infrequent. The most important of these are:—

(1) *Potro River.*—The grey clayey sand covers an area of approximately 300 x 250 feet and averages 6 feet in thickness. Estimated reserves are approximately 16,000 cubic yards.

(2) *Bia River south-west of Wiawso*—A grey clayey sand occurs on both sides of the river and covers an area of approximately 300 x 150 feet. The sand deposit varies between 2 feet and 10 feet in thickness and probably averages 6 feet. An estimated quantity of 10,000 cubic yards is available.

(3) *Menam River near Menam.*—A fine-grained grey sand on the east bank of the river covers an area of 600 x 750 feet and varies in thickness from 8 feet to 4 feet, 200 yards away from the river. The sand is free from clay and an estimated quantity of 100,000 cubic yards is available.

(4) In addition to these deposits there are small deposits beside the Emofa river west of Akutuasi and the Asemensa river south of Akutuasi.

(b) Voltaian Area.—The rivers of the Voltaian basin are not well enough graded to allow large deposits of sand to accumulate and apart from small deposits, which are widespread, for example in the Kokode, there are no large deposits between the southern escarpment and the river Ongwam.

Along some of the tributaries north of the Ongwam a few important deposits do occur, although they are remote from large centres of population. They occur as follows:—

(1) Along a tributary 1 mile east of Abodiem is a grey sand deposit which extends over a distance of 0·75 mile, is 200–400 feet wide and more than 7 feet thick. The sand contains a small clay fraction. 480,000 cubic yards are estimated to be available.

(2) Along a tributary 1 mile west of Abetinsu is a deposit of yellow-grey sand which covers an area of approximately 30,000 square yards and is more than 6 feet thick. The grains of quartz are slightly coated with clay. Estimated reserves amount to 60,000 cubic yards.

(3) *Pame River.*—The Pame river meanders for 7 miles north of Pame and clean clay-free yellow quartz sand which averages 10 feet in thickness is confined to the river bed.

North of Pame the river is bordered by sand over a length of 2 miles. The deposit covers an area of 250,000 square yards, and averages 6 feet in thickness and an estimated quantity of 500,000 cubic yards is present.

4. CLAY

Small clay deposits have been found in the Precambrian lying at depths of 6–8 feet below the surface. These deposits are not considered to be of economic value. In the Voltaian area a stiff grey clay occurs in the Ongwam near Abodiem. In the Pame river 1 mile north of Pame, clay 1–3 feet thick occurs in the river bed over a distance of several miles below a sandy overburden 1 foot thick.

5. GRAVEL

Small amounts of quartz gravel occur at the following localities:—

River Sampong, west of Wiawso.
River Menam, near Menam.
River Echurinayua, south-east of Nsekuaso.
River Nsekua, north-east of Nsekuaso.

6. WATER SUPPLY

South of the Voltaian escarpment the area is well watered with numerous perennial streams. These supply a continuous source of water for the villages and towns on the Precambrian outcrop. The main problem in these areas therefore is not the locating of water but ensuring that the supply is clean and uncontaminated.

On the Voltaian outcrop the provision of water supplies is more difficult as many of the springs issuing from, and the rivers which flow on, the Voltaian rocks dry up during the dry season. The only river which can be called perennial within the Voltaian basin is the Ongwam and even it may, in bad years, be reduced to strings of pools.

(a) Agogo Water Supply.—This town is situated on a pass through the main Voltaian escarpment and is underlain by the Agogo clay gall sandstone formation. Water supplies until recently were obtained from the Kruwire stream, wells and Henderson boxes, most of which dried up in December-February period. The Kruwire stream is also polluted and carries schistatoma worms. It is therefore essential that the town be supplied with a reliable clean water supply. As there are no perennial streams in the area from which a supply could be obtained, four boreholes were sited by L. O. Gay and the writer, and have since been drilled. The sites are illustrated on the site plan for Borehole A8 Agogo.

At first of these boreholes A4, was situated between the town and Agogo resthouse in the valley. This was thought to be an extremely good site as the borehole would probably intercept the North Agogo fault in depth. The borehole penetrated through 94 feet of the Dente shale and siltstone before water was struck at the boundary between the latter formation and the Agogo clay gall sandstones. It is not known if this boundary is stratigraphical or the fault but it seems probable that it is the former. The supply was only small and the hole was abandoned at 298 feet.

The second borehole to be drilled was A6 on the banks of the Kruwire stream. In this hole 660 feet of Agogo clay gall sandstone were penetrated before the Tarkwaian quartzites which form the Precambrian basement in this area were encountered. This borehole yielded, just after completion, 1,500 g.p.h. and the majority of this supply come from a poorly cemented and stone just above the Tarkwaian–Voltaian junction. This sandstone however was not self supporting and after a time slipped into the bottom of the borehole, choked it and reduced the yield.

Borehole A5a was the next to be drilled in the east bank of the Kruwire valley north-north-east of Agogo. This borehole proved 795 feet of Agogo clay gall sandstone resting on Tarkwaian quartzites. The water in this hole was also struck at the bottom of the sandstones in similar strata and running sand in the bottom of the hole was again experienced. The original yield of this borehole was 1,600 g.p.h. but this, as in B.H.A6, was later reduced.

The fourth borehole was sited by the side of the timber road between A6 and A5a. The hole reached a depth of 610 feet and may have just reached the Voltaian–Tarkwaian boundary. The yield from this hole was 700 g.p.h. The level of the aquifer is not known.

These boreholes indicate that drilling for water in the Agogo clay gall sandstones can be fairly successful and that the most likely zone for obtaining a fair supply is at the base of the sandstones. Supplies may be obtained at shallower depths where the rocks are well jointed but otherwise the sandstone is too well compacted and cemented to hold water.

(b) General Conclusions.—From the information from this and adjoining areas the following tentative generalisations may be made.

(1) Within the Voltaian basin boreholes should only be used if there is no suitable perennial stream which could be impounded to provide a supply.

From a consideration of the borehole information obtained and the lithology of the Voltaian rocks it seems probable that good water supplies may be located in the following positions by drilling.

(1) At the base of the Agogo clay gall sandstone and occasionally higher in this formation where conditions are suitable.

(2) At the contact between the Dente sandstone and Dente shale and siltstones. Small supplies may only be expected at this level as the overlying sandstone is impervious except where well jointed. Drilling in the Dente sandstone should be avoided if possible as the rock is hard and drilling may be slow and expensive.

(3) At the contact between the Chirimfa shales and siltstones and the Dente sandstone, and in the Chirimfa shale and siltstones below the Chirimfa sandstone. This is considered to be the best horizon for hitting a good supply as the overlying sandstone is permeable and also porous and ground water can filter down to be held between the shale bands or above the Dente sandstone in the Chirimfa shale and siltstone formation.

(4) In the Chirimfa sandstone supplies may be expected at any level in this formation depending on local conditions.

(5) In the Sene formation, at the junctions between the sandstone beds and the shale beds.

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PLATE NO. 1

Outcrop of Agogo Clay gall sandstone.

PLATE NO. 2

Basal conglomerate at contact between Agogo clay gall sandstone and Tarkwaian quartzite.

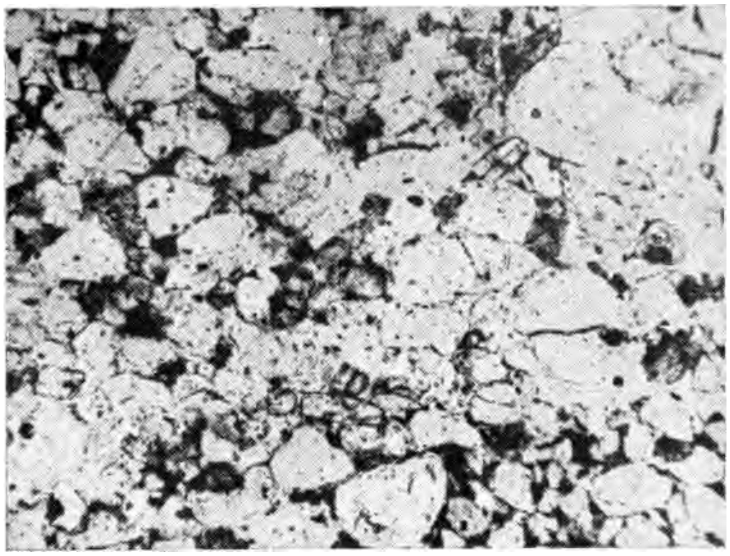

PLATE NO. 3

Agogo clay gall sandstone.

PLATE NO. 4

Agogo clay gall sandstone. Magnification x 100.

PLATE No. 5

Dentebuom cliff 1·5 miles south of Agogo.

PLATE No. 6

Dente shale and siltstone.

PLATE No. 7

Washout in Dente shale and siltstone.

PLATE No. 8

Wave ripple marks, Dentebuom.

PLATE NO. 9

Shale showing suncracks, Dentebuom.

PLATE NO. 10

Shale showing suncracks infilled with siltstone.

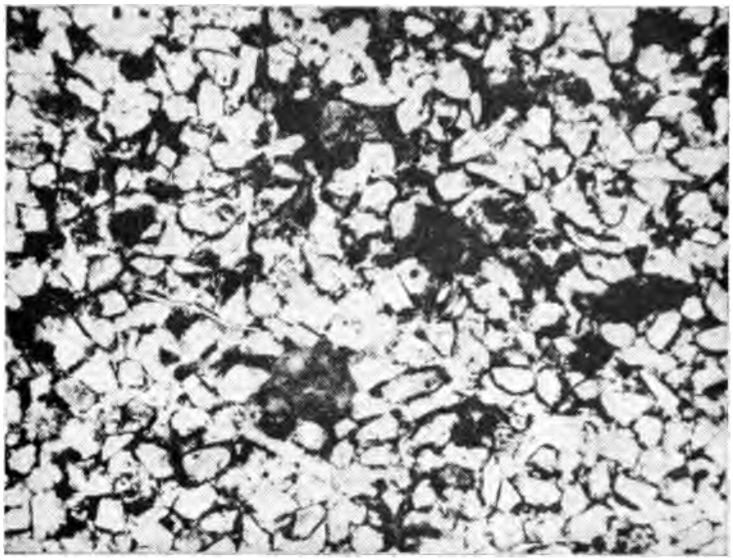

PLATE NO. 11

Dente siltstone.
Magnification x 100

PLATE NO. 12

Dente sandstone.

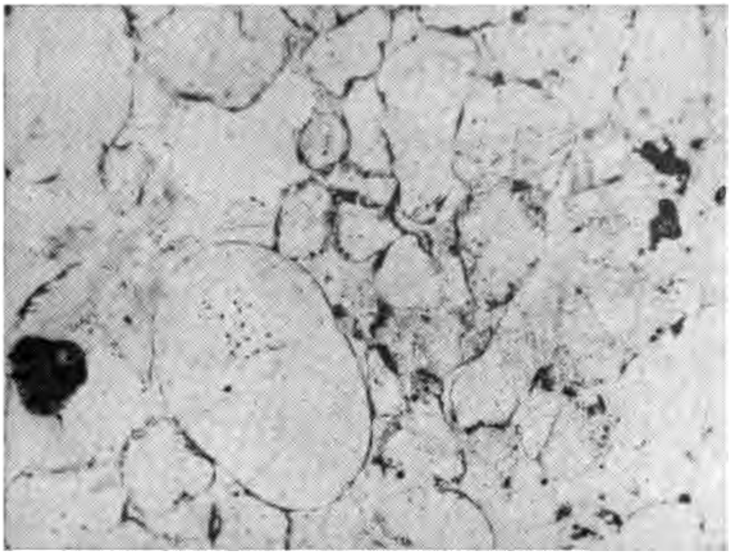

PLATE NO. 13

Dente sandstone.
Magnification x 32

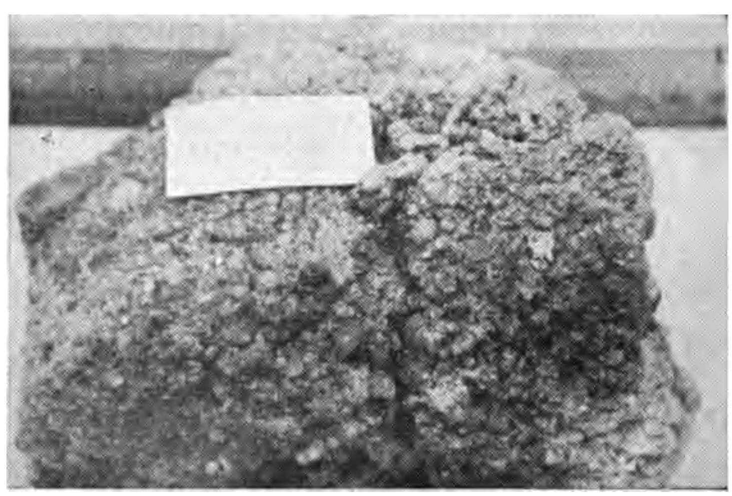

PLATE NO. 14

Conglomeratic facies
of Dente sandstone.

PLATE NO. 15

Bomfobiri waterfall, river Ongwam.

PLATE NO. 16

Sandstone pavement formed by Dente sandstone.

PLATE NO. 17 *Panoramic view down Ongwam valley.*

PLATE NO. 18
Chirimfa siltstone.

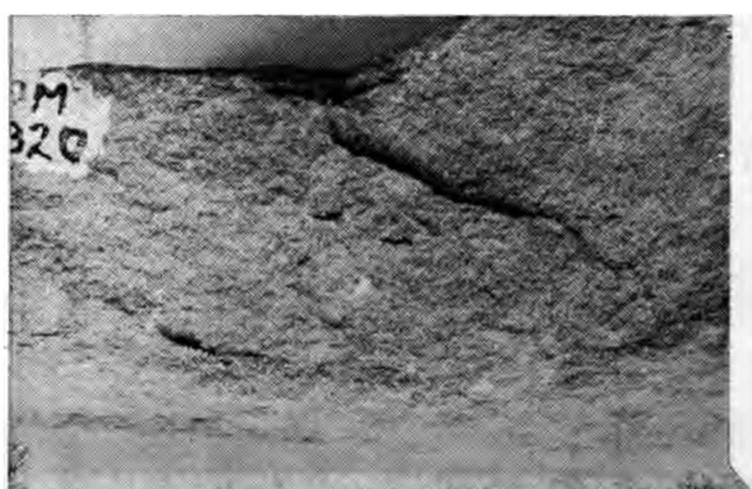

PLATE NO.19
Chirimfa arkosic sandstone.

[redacted]

[redacted]

Verify 3 ~~pockets~~
~~contain all~~ sheets

UPPER VOLTAIAN

LOWER VOLTAIAN